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THE NUMBER FORMS OF A BLIND SUBJECT

By RAYMOND H. WHEELER and THOMAS D. CUTSFORTH

Number forms in the adventitious blind are sufficiently rare to warrant the description of a case. The reagent whose forms are here described is T. D. C., one of the authors of this article and a former major student in psychology at the University of Oregon. On March 9, 1917, detailed descriptions, in writing, of these forms were obtained and filed away. On August 15, 1919 the reagent was unexpectedly asked to describe these forms again. These latter descriptions were then compared in minute detail with the earlier descriptions.

The reagent has a simple digit form for the numbers 1—10, a tens form for the numbers 10—100, a hundreds form for the numbers 100—1,000, a thousands form and so on into the millions. He also has a week form, an alphabet form, a month form and a century or date form. He also has numerous varieties of synesthesia.

The lower right hand figure in the accompanying cut is the reagent's form for the numbers 1—10. Each rectangular section is sharply differentiated from its neighbor by means of hue and brightness qualities which stand for separate numbers. The numbers themselves are never visualized and when the subject uses this form he translates the colors into numbers vocal-motor fashion. The form appears in space in front of the reagent's face at a distance of about one meter. The entire form is about fourteen centimeters long and two centimeters in width. The following are the colors for the numbers 1—9, taken verbatim from introspections.

	On March 9, 1917	On August 15, 1919
1.	white	whitish, nothing but brightness
2.	dull grey, tinged with yellow, like old weather beaten boards	grey, slightly yellow, like old weathered straw
3.	like 2 but more reddish	light, faint reddish brown
4.	like 3 but darker	peculiar brown, like fir boards

5. muddy black	a dull black, like spilled ink
6. white, like 1, identified by position	white, like ivory
7. dark, muddy blue	bluish black, somewhat like graphite, but darker
8. grey, tinged with yellow	very poorly saturated yellow
9. dull grey tinged with yellowish green	dark grey with greenish cast; a bottle green

The tens form consists of ten of the small digits forms placed end to end in a direction upward and away from the reagent toward the right, beginning at a point in front of his left shoulder. Each of the smaller unit forms represents figures from 1—9, 10—19, 20—29 etc. The extreme right end of the form bends more sharply away from the subject and upward less abruptly enabling him to visualize the entire form almost at once and to make use of it with less extended eye-movements. With the exception of the numbers from 10—19 each intermediate figure in the various ranges of tens is colored according to the final digit.

The hundreds form is a product of tens forms. The colors are determined in similar fashion. The thousands form is a product of hundreds forms and so on. In all of these latter forms the colors represent ranges and not individual numbers. For example in the hundreds form there are ten colors, representing the ten ranges of ten numbers each. In the thousands form there are ten colors representing ten ranges each of 100. When the reagent thinks of large numbers several forms are used and held in consciousness at the same time, the smallest form in the foreground and the larger forms localized back of the first one in order of their size. This can best be understood by reference to an analogy. Let each form be represented by a framed picture. The several forms in use at one time would then be represented by a series of framed pictures set up one behind the other, each one larger than the one in front of it and resting on a higher level. The individual forms retain their identity by their localization and by a colored halo which latter varies with each form. The halo would be represented by the frame of the picture. The halo or background for the hundreds form is black; for the thousands form it is silvery white; for the hundreds-thousands form it is reddish-brown and for the millions form it is yellow.

The following illustrates how the forms are used. When the reagent thinks of the number 3,591 a thousands form

appears in the background of a visualized field, with the appropriate section in the focus of attention, namely, the third section from the left hand end. Directly in front of this lies the hundreds form and with a "slide rule" effect the reagent's line of regard shifts to the fifth section of this latter form. A second shift of his line of regard brings the reagent's attention to the ninth section of the tens form which latter lies slightly below and in front of the hundreds form. A final shift carries his regard to the first section of the digits form which lies at the left hand end of the tens form, when thinking of large figures. The rapid use of number forms has been described several times in the literature. Diamandi's success as a lightning calculator was in part due to the use of a number form.¹ In the present case this fact is all the more remarkable for the reason that the numbers are not visualized. Colors are used as substitutes. Hennig,² Grüber,³ and others have pointed out that in cases of synesthesia colors have been used to represent numbers in performing mathematical operations. Galton⁴ seemed to have been able to substitute odors for mathematical symbols in simple operations of adding and subtracting.

As an example of such a substitution of colors for numbers we give the following instance of counting in terms of colors. The authors were giving mental tests at the Oregon State School for the Blind. The reagent was in the act of counting the number of words which one of the blind pupils was giving within the interval of three minutes. He began by counting the words in vocal-motor fashion but in a short time vocal-motor imagery became confused and he was obliged to cease relying upon inner speech. In the meantime, however, each verbal image had been accompanied by its appropriate color, localized properly in the number forms. From this point on until the end of the three minutes the reagent, who was then acting as examiner, was able to keep track of the number of words which the pupil was reciting to him. The last color was then translated into the appropriate figure.

When the reagent is given large numbers to locate in these forms, eye-movements can be seen as he shifts his line of regard from one form to another or from one part of the

¹ See Philips, *Genesis of Number Forms*, *Amer. Jour. of Psychol.*, Vol. 8, 1897, 506-527.

² *Entstehung und Bedeutung der Synopsien*, *Zsch. f. Psychol.*, 1896, Vol. 10, 113-122.

³ *L'audition colorée*, *Cong. inter. Psychol.*, Paris, 1889.

⁴ *Arithmetic by Smell*, *Psychol. Rev.*, 1894, Vol. 1, 61-62.

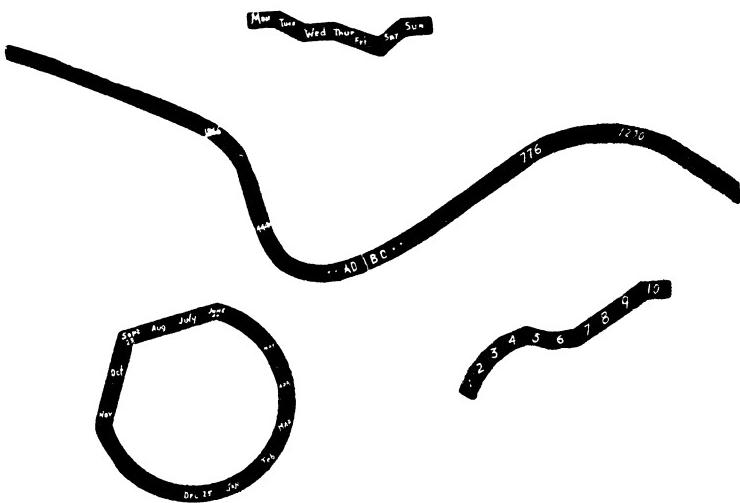
same form to another part. The extent of eye-movement is proportional to the size of the forms which are being used. Voluntary or artificial checking of these eye-movements impedes the reagent in the use of the forms.

The upper figure of the cut is a miniature copy of the reagent's week form. Each day of the week is represented by a colored section in the form. Monday is dark, inky blue; Tuesday is pale brown; Wednesday is a very dark green; Thursday is a dark orange-red; Friday is a "russet" yellow; Saturday is a muddy, curdled black and Sunday is white.

The lower left hand figure is his month form. Again no letters or writing are seen in the form but the months are represented in colors. The flattened portion of the form corresponds to vacation periods of the school year. The subject is unable to recall the conditions under which the form originated.

The long figure in the cut represents the century or date form. It is about four centimeters wide and a meter long. It is visualized upon a globe-map of the world and upon this background appear dark, faintly colored areas as continents and light blue areas as oceans. The dates appear in color, not in figures or in writing. 1900 lies above the eastern coast of the United States; 1066 A. D. lies just above the British Isles; the dividing point between A. D. and B. C. in the region of the Mediterranean Sea and so on. The dates are colored according to their component digits. This form originated when the subject was first studying geography, and is used constantly as an aid in fixing and in recalling dates.

The figures in the cut are photographs of card-board models made by the reagent himself. In the actual forms there are no figures, the figures being inserted merely to explain the forms. The photograph was taken in March, 1917. In August 1919 the reagent made new models of all forms. During this interval of time none of these forms had changed except in minor degrees of saturation or in slants of some of the lines, and these differences may have been due to inaccuracies in making the model or in describing the colors. One exception must be noted, however. The century form originally slanted upward at its extreme right end. In the cut it is seen slanting downward. This change occurred during the time that the reagent was in college, and can be traced to the repeated use of this form while the reagent was studying Babylonian History. Since then the form has resumed its original upward slant.



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